

## The Code in Practice – “Communications are the Key”

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### **ABSTRACT**

*This paper describes how the NATO Code of Best Practice on the Assessment of C2 has been applied within the UK procurement project to acquire a new generation of formation level communications.*

**Key Words:** *Command, control, assessment, best practice.*

### **1.0 A HISTORY OF C3I MODELLING**

Operational research (OR) has addressed many topics and issues in its relatively short history. Most of the dark corners of corporate, industrial, and governmental competence have been illuminated by the bright light of OR. Some clients of the art have even complained at the brightness and have contrived to deflect the beam, perhaps even far enough to dazzle the decision-makers themselves.

One area of particular obscurity concerns investment in information generation, handling, fusion, and dissemination, known collectively as information management. In all domains, not just the military, information systems investment has proven difficult to justify in terms relevant to the central business objectives of the enterprise being served.

#### **1.1 The ‘Pre-History’**

In the military domain, information and command & control are inseparable, although it is arguable that C2 is a considerably wider term than information management. It entails issues of morale and motivation, for example, although even these might in some minds be merely further forms of ‘information’ to be handled and processed. The ingredients of communications (C3) and intelligence (C3I) are recent additions to the mix of dimensions of the information ‘problem’, but they do not fundamentally change its nature. There are from time to time attempts to add further richness: the 4<sup>th</sup> C (for consultation) is glimpsed but rarely these days. It is notably present in NC3A’s title.

The origins of OR, paradoxically for newcomers to the business, lie in issues arising from the interplay of:

- people as decision makers,
- sensed information (with attendant uncertainty), and
- the potential of platforms/fire channels to achieve desired ends.

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The classic example is the work carried out in World War 2 on UK air defence in the Battle of Britain.

Why is this a paradox to newcomers?; because we find ourselves here, some 60 years later, arguing for a re-balancing of the conduct of OR in favour of this broader view despite the progress of the intervening years.

### 1.2 The History

Much operational research, particularly in the military domain, has adopted a single technique of direct or ‘literal’ simulation. This paradigm entails modelling the motion of platforms of interest in three dimensions, with an overlay of probabilistic consideration of weapon delivery, impact, and detonation, where appropriate. In this approach, there is, at best, only implicit representation of information and knowledge, and it is usually not considered to vary within the representation. There is no human presence in the simulated environments, and acts of communication are not represented. It can be appreciated that this representation is a long way from reality. Effectors contrive to present themselves in the right place at the right time to engage with the opposition without any need for communications channels and the intelligence and orders they provide.

### 1.3 Modern Times

That notwithstanding, useful studies have been conducted during the ‘history’ phase in which C3I issues have been given a place. Their inclusion has usually been contrived through judicious use of intermediate parameters ‘tweaked’ to represent for example, different information states, or organisation policies. There is a sense in which this approach is fully legitimate, but it must be acknowledged that from the perspective of a customer for an OR study, it might not be perceived as transparent and so not legitimate.

Such thinking led the NATO Defence Research Group to propose the formation of an Ad Hoc Working Group to consider the question of what could be done with existing modelling approaches and methods to represent C3I factors, so allowing the C3 equipment agenda to be taken forward with assessment support. The Group’s Report [1] noted that whilst C3I studies were not completely frustrated by the perceived lack of methodology, there were certainly improvements in approach which could be specified and codified for wider consideration and application. Amongst these was the recommendation that models should be built with a C3I perspective *at their foundation*, a suggestion which has been adopted as policy by UK defence practitioners. DRG Panel 7 accepted the recommendation of the AHWG Report that a Research Study Group (RSG) be formed to “promote and co-ordinate C3I modelling activities”. This became RSG19 (later SAS 026) tasked to formulate and draft a code of best practice (COBP) in command and control assessment. UK authorities later produced a condensed version of the COBP which has now been adopted by SAS026 UK has also produced a risk register tool for C3I assessments, based on the COBP, to assist its own staffs.

### 1.4 Today

The code of best practice [2] is now an established part of the UK analysis and assessment scene. It has been briefed to senior decision makers in the UK MoD, and is regularly cited in the research programmes which support the UK’s acquisition programme. It has even been used as a touchstone of best practice for domains of assessment other than command and control.

To illustrate such usage, the remainder of this paper is devoted to illustrating the UK’s use of the COBP through its application to the assessment of proposed investment in new communications systems for UK forces, in particular the replacement of our ageing Ptarmigan ‘formation’ level land communications system, a project known as Falcon.

## **2.0 COMMUNICATIONS SYSTEMS ASSESSMENT IN THE UK**

### **2.1 Introduction**

In UK practice, the assessment of communications equipment and systems has three key components: the physics of propagation and the engineering of electronic devices, and the logical behaviour of digital systems. In the UK, models have been created which deal with each of these independently, and with mixes of all three. The best models, though also the most complex and so most expensive, make due allowance for the impact of analogue properties on digital behaviour. Note, however, that no representation of message content or the consequences of message arrival is attempted in these models.

### **2.2 Physics**

This area of modelling addresses generation of signal power, inter-visibility of emitters and receivers, propagation including terrain and, where appropriate, ionospheric effects, and antenna design. The performance of each link is characterised by the signal to noise (S/N) ratio it achieves. A good example of this class of model in UK practice is the Communications & Electronic Warfare Simulation (CEWS) which has been through many generations in support of land based communications and electronic warfare optimisation and acquisition.

### **2.3 Digital Communications Systems**

This class of models is often a derivative of, or a component of, the design process of digital communications systems. The model is comprised essentially of an emulation in software of the system's behaviour. Much of the real system software is capable of being incorporated into the emulation. Validation is clearly a less significant issue for such models. A typical output from this class is insight into the robustness of a given communications protocol under the deleterious impact of interference or counter measures. However, note that each system design will tend to spawn its own tailored simulation toolset with restricted applicability to other communications systems problems.

## **3.0 COMMUNICATIONS PROCUREMENTS IN THE UK**

### **3.1 Introduction**

The UK is currently engaged in four key communications procurement projects bridging all levels of command from tactical to strategic:

- Bowman will provide tactical services to the British Army in the field,
- Falcon will link formation level entities such as battlegroups, and their command infrastructure,
- Cormorant offers services to joint command, and
- Skynet will provide long-haul satellite-like services to all defence entities.

### **3.2 Bowman**

Bowman will operate at the tactical level, and will comprise HF, VHF, UHF, Personal Radio, voice & data services. It will also automatically determine the position of each radio and report that position over a broadcast net. It will be secure and counter-measure resistant. It replaces the current Clansman system of HF and VHF manpack and vehicle mounted radios.

### 3.3 Falcon

At formation level, Falcon will offer voice and data services to all UK Forces and Services, replacing the Ptarmigan system of land communications and the RAF’s Tactical Trunk System (RTTS). It will enable joint and combined warfighting with a wide range of allies. Falcon will be a deeply incremental acquisition in four phases.

### 3.4 Cormorant

The formation of the UK Joint Rapid Deployment Force (JRDF) made evident a requirement for bridges between Sea/Air/Land Service Joint Force Component ‘HQ’ Units, to enable Joint command to be exercised. The Cormorant procurement will satisfy this requirement.

### 3.5 Skynet

The existing Skynet programme of UK satellite communications is moving to a new generation of services to be provided by a public-private partnership arrangement. The next tranche will be known as Skynet 5 and will be comprised of satellite and other long-haul system technologies.

### 3.6 UCS

The totality of UK communications ambition is the generation of a Unified Communications System (UCS) in which all services required are offered to all users on a transparent, high availability basis. The roles and relationships of the systems being procured is shown in fig. 1. It should be noted that there are other equipments in service or procurement with which Falcon must be compatible:

- RAF Tactical Trunk System (RTTS);
- Local Data Communications Network (LDCN) also known as the Deployable Local Area Network (DLAN), offering communications services within airfield environments; and
- Gateway provision to other nation’s systems (GATE).

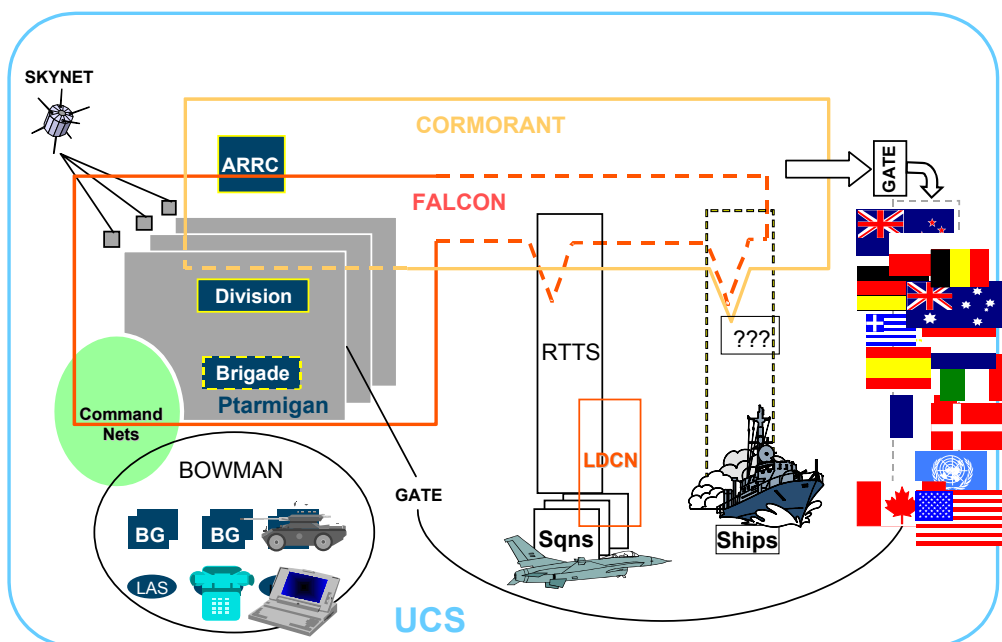


Figure 1: UK Communications Systems.

## 4.0 THE COBP – THE “BEST PRACTICE” PROCESS

The central concern of RSG19 was the perceived need for a clearly described sequence of actions to specify how best practice in C3I assessment could be exercised. The process agreed is shown in fig. 2. The process orientation of the Code has proven very helpful in offering a defined route through the complexities of the Falcon procurement. The process description is used in this paper to describe how the Code has impacted upon the approach which is being employed in the Falcon Assessment.

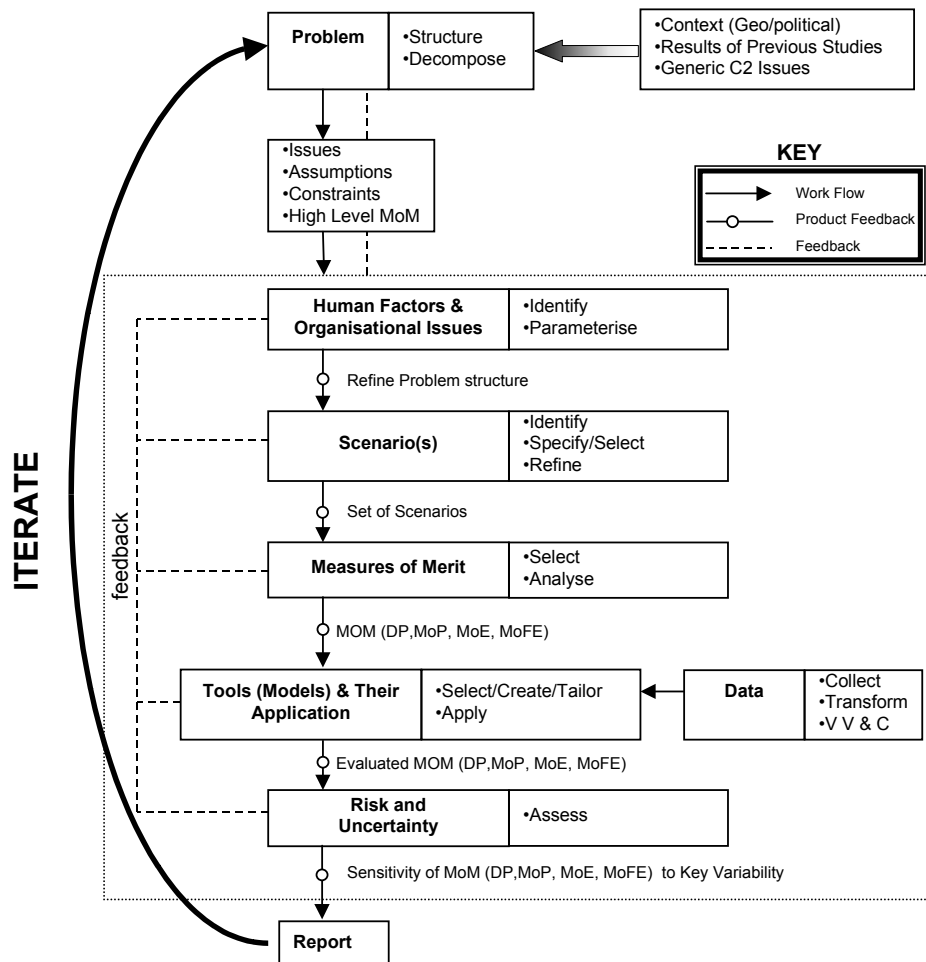


Figure 2: The COBP Process for C3I Assessment.

### 4.1 Assessment Context, Existing Knowledge & Issues

The context of the Falcon procurement is operations in both joint and combined circumstances and in a wide range of operational scenarios. There is also a managerial imperative to follow the precepts of the UK “Smart Procurement” initiative. For example, the project has been configured as a programme of four increments in order to reduce the risks arising out of the increasing pace of technology development. Existing studies relevant to Falcon include those on Bowman operational benefits, Cormorant operational benefits, and the requirement definition study for Falcon. This latter study aimed to identify in operational terms why the system was needed, as well as to give outline indication of the justification for the proposed scale of investment. Generic command and control issues for the Falcon procurement include the impact of communications systems properties on flexibility of UK forces in the light of changing doctrinal approaches and structural developments.

## **4.2 Problem Structure & Decomposition**

It has usually been assumed in similar previous acquisitions that new communications technology is inherently a good thing. However, a number of difficult, not to say disastrous, acquisitions in both military and civil government domains has persuaded decision makers and their advisers that a new approach is necessary. The key realisation is that the purpose of investment is the delivery of benefits, both operational and financial. The essential structure of the ‘problem’ domain for Falcon is, therefore, identification and quantification of the benefits (and disbenefits) of the modernisation of communications infrastructure. In the Falcon assessment, we have conducted a benefits identification workshop amongst the military operators and communicators. This enabled the assessment team to map the generating links between the benefits required from the investment and the (already declared) User Requirement. Note that the User Requirement is conventionally expressed in terms that are wider than benefit delivery for usually sound military reasons.

The decomposition of the assessment for Falcon resulted in the following areas of decision-maker interest:

- Options for the use of technology,
- Migration paths from legacy to future systems components,
- Doctrinal development (manoeuvre and pace of operations),
- Options for different operational organisations,
- Different procurement modes,
- Different equipment suppliers,
- The significance of boundaries with related projects.

It is expected that further factors will be identified as the Falcon programme evolves through its incremental procurements and associated expenditure submissions.

## **4.3 Human Factors & Organisational Issues**

Human factors figure in increasing strength in UK MoD thinking and policy as demographic development and trends in the employment market make themselves felt. The MoD response to these developments has been to seek yet further efficiencies in the deployment of human resources.

Equipment design has been subject to tests of human ergonomic compatibility for many years. Above that, task design is now firmly on the human factors agenda. The next level of concern is the design of co-operating teams of human actors; this is organisation design. UK MoD force development and doctrine agencies are again showing substantial interest in the link between HQ design and operational effectiveness. As budgets are squeezed and front-line forces are reduced, there are inevitable questions about the size and shape of the human command and control organisation needed to employ them effectively.

UK R&D management has responded to these developments by progressive investment in programmes to identify the relevant aspects of human performance and to quantify them in the form of executable models. This work has been reviewed in a survey of guidance on the use of HF knowledge in C2 operational analysis [3].

For the Falcon era and operational applications, the prime human factor issue is the flexibility of HQ staff to optimise their roles and activities. In respect of organisation, the issues are the impact of doctrinal drivers and constraints on the effectiveness and efficiency of HQ organisations.

#### 4.4 Scenarios

Communications are, of course, a constant feature of every scenario. The key scenario issues are the obvious ones:

- capacity to satisfy the demand made of the systems during the most intensive phases of operations, including the implications of concurrency of operations in different theatres;
- security within NATO and coalition operations;
- the variety of terrain and force dispositions within the relevant geographies.

To meet these requirements, the Falcon assessment will address five different scenarios drawn from the UK’s standard set of MoD approved scenarios. The range covers intensive warfare as well as peacekeeping operations, both including a variety of terrain. A further key requirement for coherence between studies will be met by exploitation of scenarios already developed for use on other studies.

Within each scenario, the assessment will examine a group of military *vignettes*:

- deployment,
- enemy air strike on an HQ,
- deep operations by joint forces,
- transition from peacekeeping to warfighting,
- coalition operations, and
- exit from theatre.

The *vignettes* offer an operational level of consideration of the benefits by the military experts.

#### 4.5 Measures Hierarchy

The COBP advises that the measures adopted to assess the benefits of the proposed investment should be construed as a hierarchy. The COBP text illustrates the general purpose hierarchy as a set of nested measures, as in figure 3.

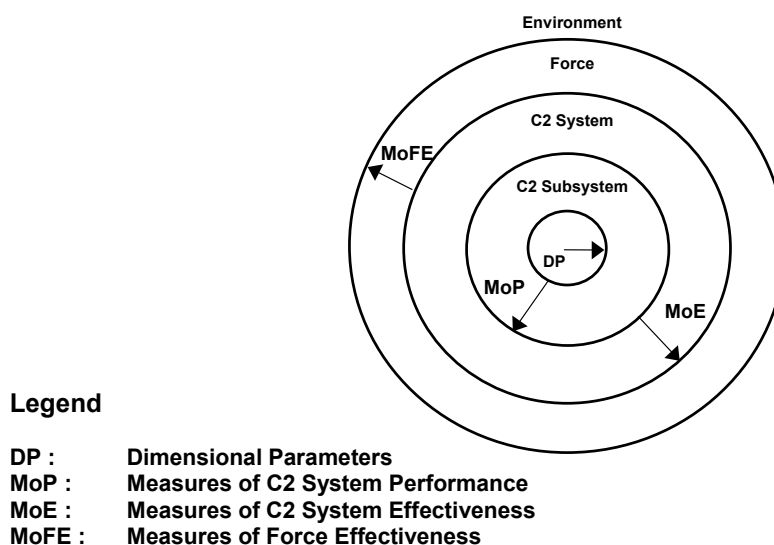


Figure 3: The General Hierarchy of Measures of Merit.

## The Code in Practice – “Communications are the Key”

In the Falcon programme of assessment, the factors which reflect decision-maker concerns and interests and are therefore most prominent in the measures hierarchy are as follows:

- **Parameters (DP):** radio and system architecture descriptors, organisational architectures, doctrinal conditions, project boundaries;
- **Measures of Performance (MoP):** Picture completeness, HQ planning efficiency, operational pace, organisation flexibility;
- **Measures of Effectiveness (MoE):** ground controlled by friendly units, enemy destroyed, casualties prevented;
- **Measures of Force Effectiveness (MoFE):** battles won, campaign success.

### 4.6 Tools, Models etc.

To quantify these measures, the Falcon assessment will adopt four key tools:

- simulation of battlefield actions and headquarters planning activities;
- benefits analysis by multi-criteria decision analysis (MCDA);
- vignette analysis by military advisory panels; and
- analytical/simulation modelling of communications networks.

Figure 4, below, indicates the likely flow and points of tool application, together with the sources of information and stakeholders which are crucial to a successful analysis.

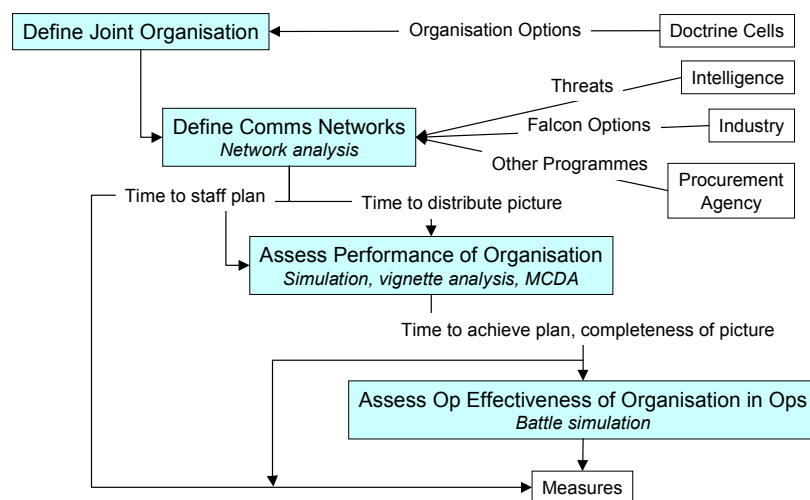


Figure 4: The Assessment Tools and Process.

### 4.7 Risk and Uncertainty

In Falcon, there are four prime risks which the assessment programme must address and manage: late option definition, late cost data, uncertain boundaries, and incorrect information exchange requirements.

The first is that the options for procurement will be insufficiently well defined to permit timely analysis by the methodology. This risk is being attacked in two ways: a set of generic option types will be defined with the support of technical expertise as the procurement programme matures which will be used to

characterise the likely performance of the final offered solutions. With good judgement, it should be possible to argue that the actual options offered are but a small step from the generics which the analysis has addressed in detail. Secondly, the bidding companies are to be asked to carry out their own network modelling to determine the performance of their bid against a pre-declared set of key parameters.

The risk of late cost data for each option arises essentially from commercial sensitivities, exacerbated by the negotiation process as the competition moves to closure. It will be managed by a similar mechanism to the problem of option definition, namely, generic cost-able options reflecting the likely commercial offerings.

It is expected that Falcon boundaries will remain uncertain or in flux even as procurement proceeds to later increments. This is natural as the competence and efficiency of the ‘Falcon’ component of the total communications network will remain relatively uncertain until equipment is actually fielded. The benefits and costs which may be legitimately attributable to Falcon will therefore clarify only slowly, so inhibiting the cost-effectiveness assessment. This risk is very difficult to manage. The approach being employed is to operate a stakeholder and procurement team liaison mechanism called (at present) the Scientific Studies Working Group (SSWG).

Uncertainty in the information exchange requirement which Falcon will be called upon to support is in effect a combination of uncertainties in a range of determining parameters. It is being addressed in part through the SSWG (mentioned above), and partly through the vignette analysis being conducted with the assistance of operational field staffs who are best placed to conjecture likely trends in the demands for messaging and other traffic.

#### **4.8 Reporting**

Reporting in of the Falcon assessment will be via the standard UK format known as the Operational Analysis Supporting Paper (OASP). This format is relatively new and is designed to bring together all the evidence supporting the need for procurement, the scale of investment proposed, and the cost-effectiveness of the options. It achieves these aims by drawing on previous work and current studies, and by outlining and justifying the tools and methods used. In this regard, the OASP concept supports the principles of thorough, validated analysis set out in the Code of Best Practice.

The OASP forms one of the supporting papers to the business case which is eventually submitted to the UK expenditure approving authorities. It is also used extensively in supporting briefings to MoD staffs during the submissions process. Many senior MoD staff will, indeed, not see the OASP, instead forming their judgement on the basis of the briefing alone. This is a key feature of the streamlined MoD decision-making process under the Smart Procurement initiative.

#### **4.9 Iteration**

A global mechanism for addressing uncertainty and risk is iteration through the methodology. Sensitivity testing will be employed in the Falcon assessment to identify key investment and other variables. The robustness of each offered solution to uncertainty in the environmental and investment variables will be identifiable by the sensitivity tests.

In addition, some global iteration has been employed within the assessment to increase confidence in its eventual success. A Requirement Definition Study was conducted some two years ago to both explore the methodology then proposed, and to examine the justification for the proposed investment in Falcon. This was a most valuable exercise in that it succeeded on both counts. It demonstrated that Falcon almost certainly represented a better route for investment than further acquisition of platforms and weapons. It also revealed a lack of sensitivity in the simulation-based, single MoE methodology which was then

## The Code in Practice – “Communications are the Key”

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being used for assessments of this kind. One result has been the enrichment of the Falcon Mo'E' hierarchy based on a more diverse set of tools and methods.

The iteration so far conducted has been highly beneficial in gaining the confidence of the customers of the assessment in MoD and Procurement HQs. It has also allowed the programme to engage with (so far) two generations of operational staffs, which though it allows trends of operational thinking to be discerned, also introduces a contribution of uncertainty into the process.

### 5.0 CONCLUSION

For the Falcon project, the Code of Best Practice has proven itself a powerful aid to good study design. It has enabled the design to meet the concerns of the procurement customer, the operational staffs, and internal analysis peer review. It has been particularly successful at addressing the ‘system of systems’ complexities of the communications systems. It has also opened up the domain of communications and command and control procurement to the doctrine and organisations staff. Finally, it has offered a helpful standard agenda and vocabulary amongst analysis practitioners involved in C<sup>2</sup> and communications / electronic warfare assessments in the UK, and with their customers.

The way ahead as seen from the UK now is two fold: further progressive application of the code to projects in the C<sup>2</sup> domain, and use of the Code, and its shortened UK version, in foundational education of analysts.

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### 6.0 REFERENCES

- [1] “The Impact of C3I on the Battlefield”, NATO DRG Technical Report AC/243(Panel 7)TR/4, dated 21 Feb 1994.
- [2] “Code of Best Practice (COBP) on the Assessment of C2”, NATO RTO-TR-9 AC/323(SA)TP/4, dated March 1999.
- [3] “Human Decision-Making in OA: Knowledge Requirements and Guideline Structure”, Sheppard, C., Mathieson, G., Corrie, N., DERA/CDA/SEA/AIR/CR000070/1.0, dated August 2000.

### AUTHOR BIOGRAPHY

**George Pickburn** has spent his career in operational research and analysis for all military domains, latterly taking a special interest in command, control, and information systems. He has also served as a ‘red team’ scrutineer of business cases for systems procurement, an experience which gave him extensive experience of assessment failure modes.



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# A history of C3I modelling . . . .



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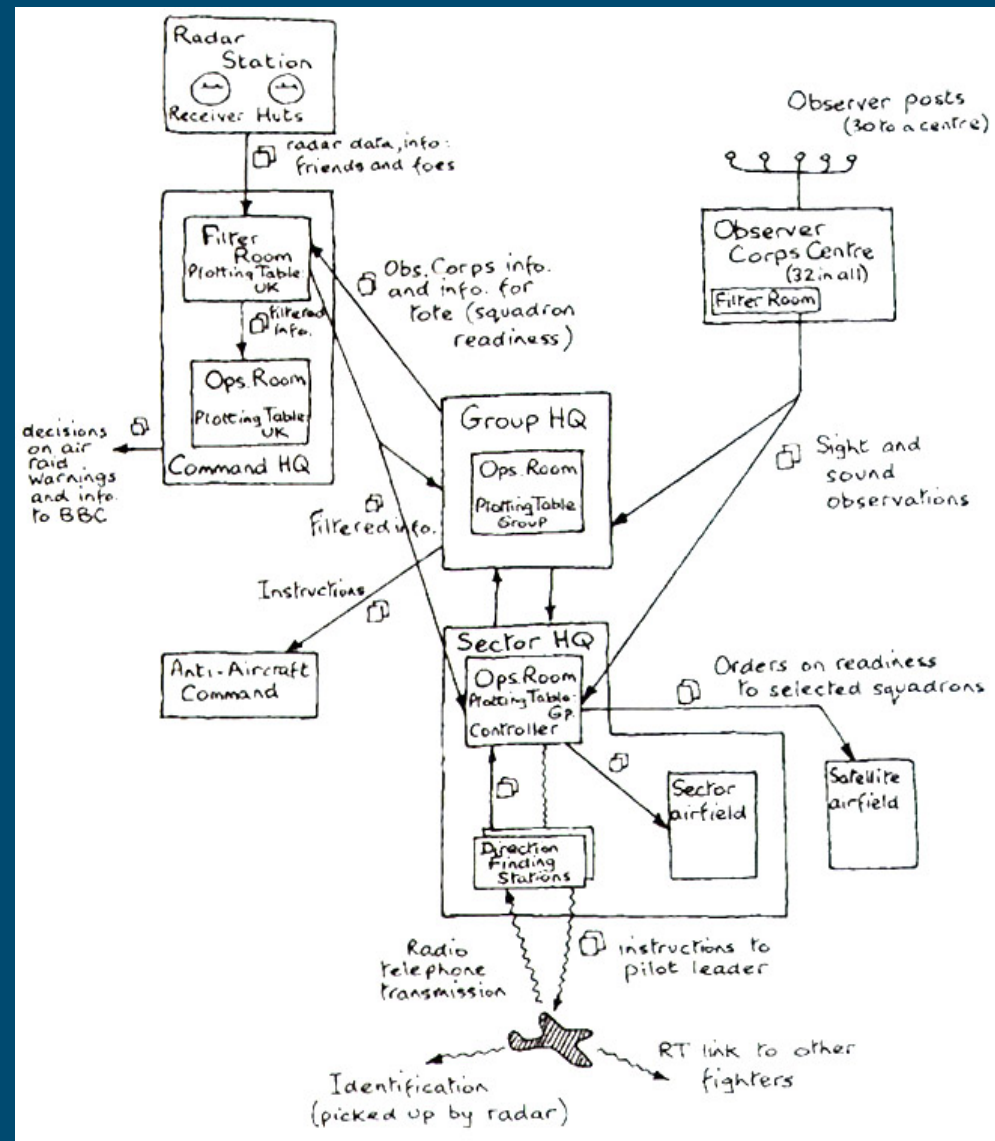
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# Pre - History

- Origins - interplay of
  - people / decision makers
  - sensed information (with uncertainty), and
  - platforms / fire channels
  - Example : work in World War 2 on UK air defence

# Information flows in the Battle of Britain

From Checkland & Holwell 1998



# History

- 'Literal' Modelling
  - 3D motion and probabilistic weaponeering
  - Implicit representation of information and knowledge - usually constant
  - No human presence
  - Communications (usually) ignored

# Modern Times

- What can we do now
- How could we do better ?
- Ad Hoc Working Group - Report
- NATO DRG decision to form RSG19/SAS 026 to write COBP
- UK condensed version of the COBP
- UK Risk Register for C3I assessments

# Today

- COBP in use in UK
- Exemplify through the 'Falcon' procurement project

# Communication Analysis in the UK

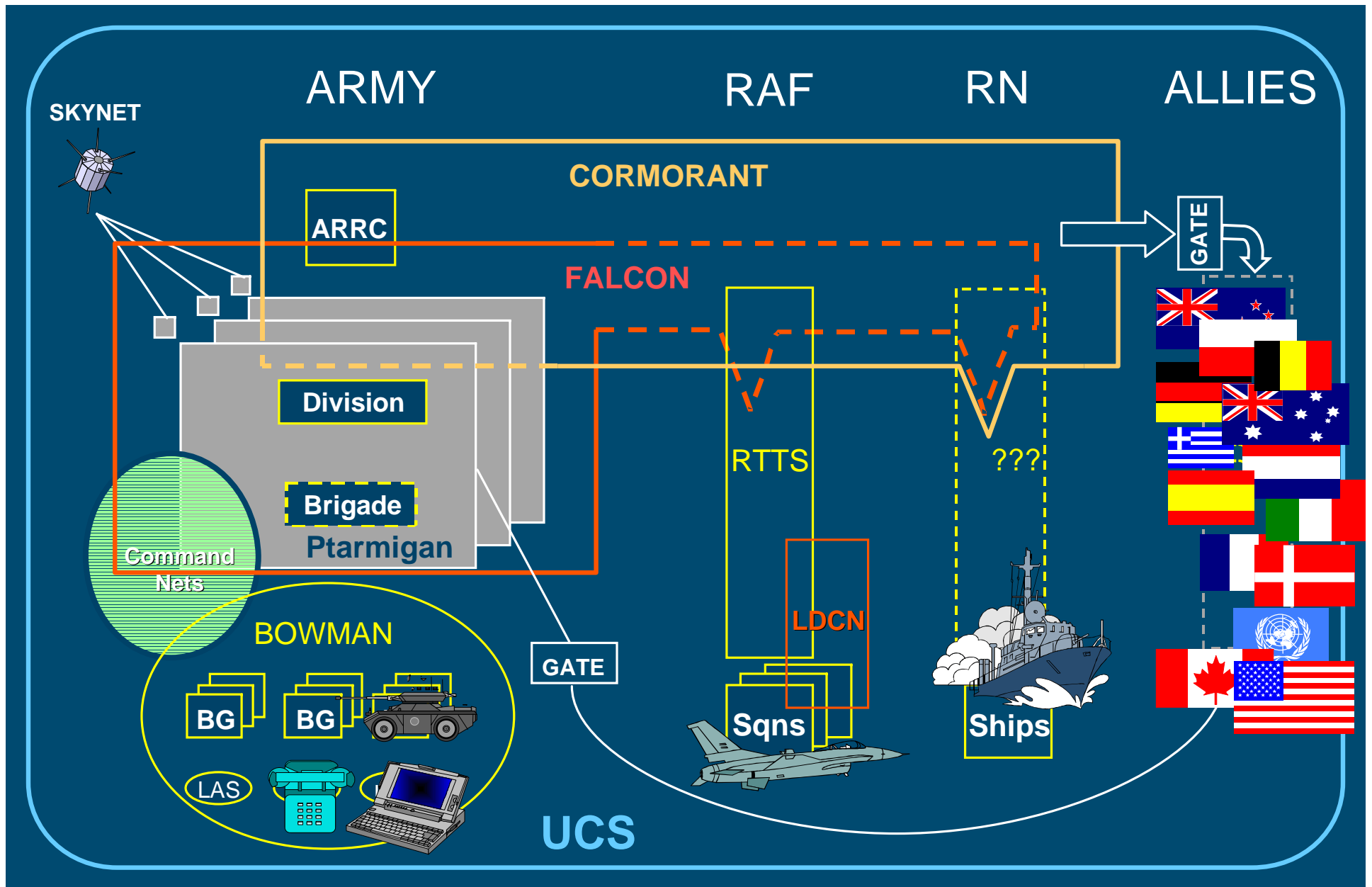
- Physics
  - Inter-visibility, propagation, ionospheric effects, power, antenna design, S/N ratio
  - e.g. Communications & Electronic Warfare Simulation (CEWS) LOGO??
- Digital systems
  - protocol robustness under interference / counter measures
  - Network behaviour at the logical level
- No representation of content or consequences

# Communications Procurement in the UK

- Bowman - tactical radio, HF, VHF, UHF, Personal Radio, voice & data, auto-position, replaces Clansman
- Falcon - Formation level comms, all Services, replaces Ptarmigan (Army system), enables Joint warfighting
- Cormorant - bridges between Sea/Air/Land Service 'HQ' Units, enables Joint command
- Skynet - strategic & long-haul comms

**‘ Life was simple before  
World War II.  
After that, we had systems ’**

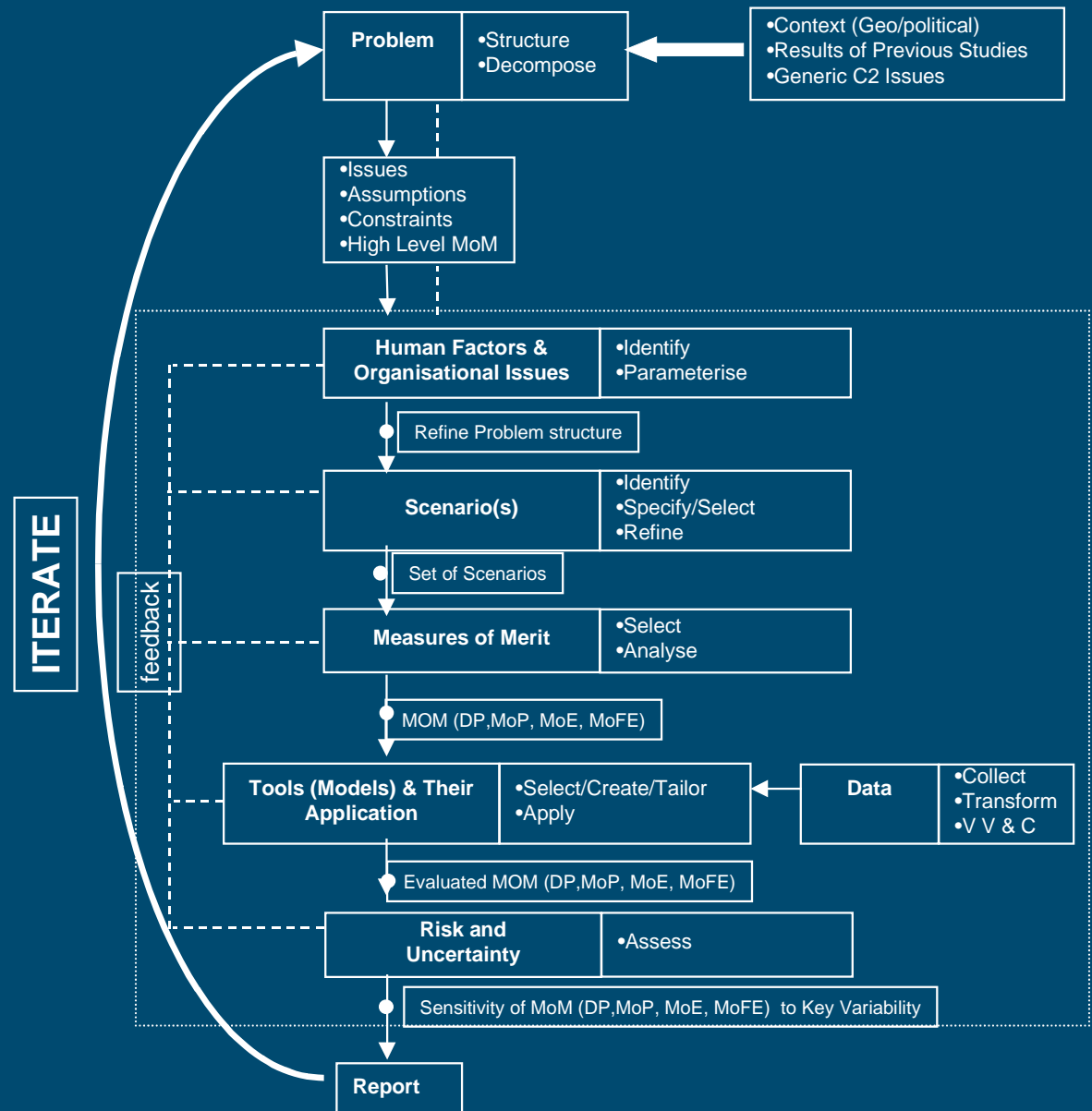
Admiral Grace Hopper.



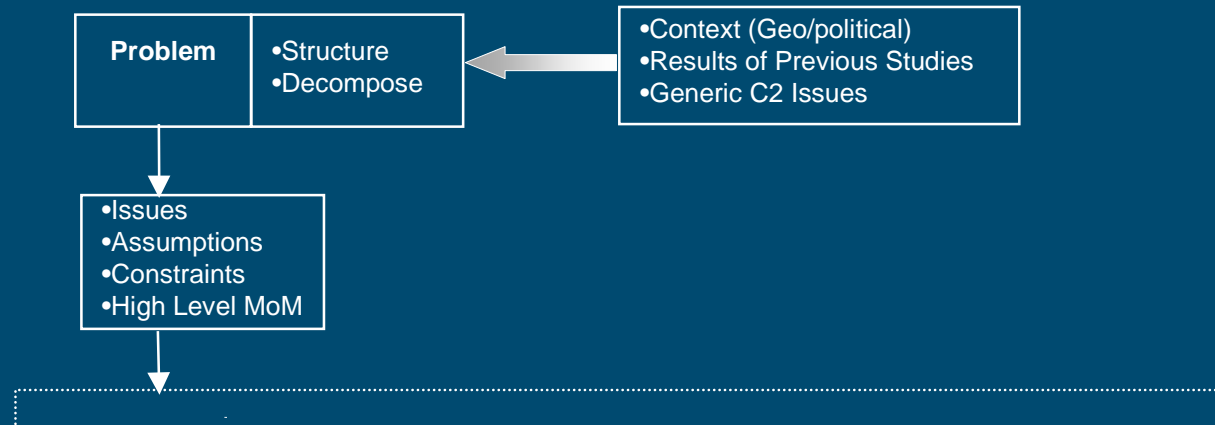
# Code of Best Practice on the Assessment of C<sup>2</sup>

*Picture of COBP  
Publication*

# COBP - The “Best Practice” Process



# Context, etc.

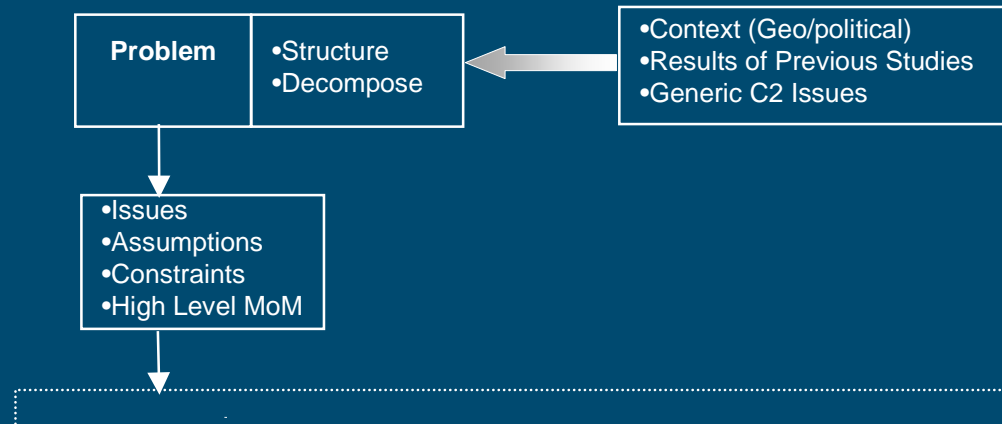


**Context** : joint & combined operations in wide range of scenarios

**Previous studies** : Falcon requirement definition study

**Generic C2 issue** : impact of communications on operating posture & achievement

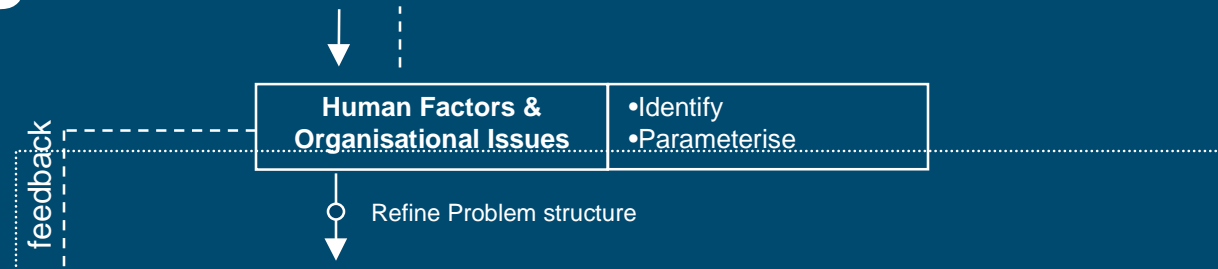
# Problem Structure & Decomposition



**Structure** : Operational benefits to be derived from modernised communications - operator benefits workshops

**Decomposition** : Options for : technology, migration, doctrine (manoeuvre & pace), operational organisation, procurement mode, supplier. Boundaries with related projects.

# Human Factors & Organisational Issues



**Human factors** : flexibility of HQ staff to optimise their roles and activities

**Organisation** : doctrinal drivers and constraints on HQ organisations

# UK guidance on use of HF knowledge in C2 OA

Human Decision-Making in OA :  
Knowledge Requirements and Guideline Structure

Sheppard C., Mathieson G., Corrie N.

DERA/CDA/SEA/AIR/CR000070/1.0 dated August 2000

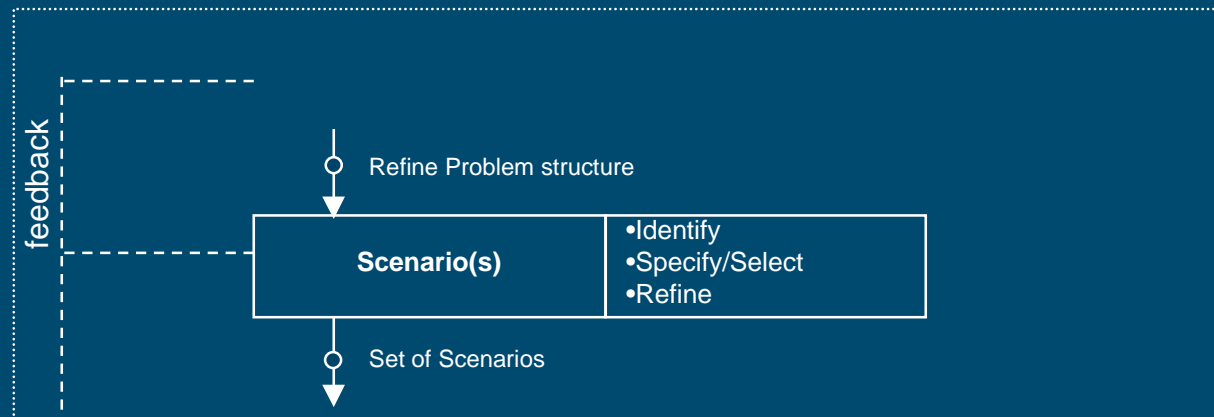


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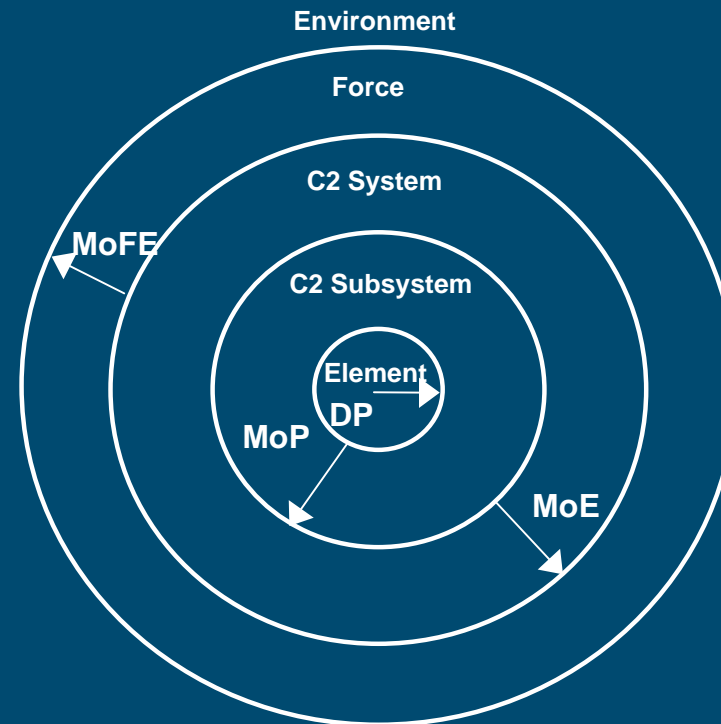
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# Scenarios



**Scenarios** : range to “test” the requirement, and to evoke/exercise the decomposition factors of interest. Size. Concurrency. Coherence with related projects.

# COBP Measures Hierarchy



## Legend

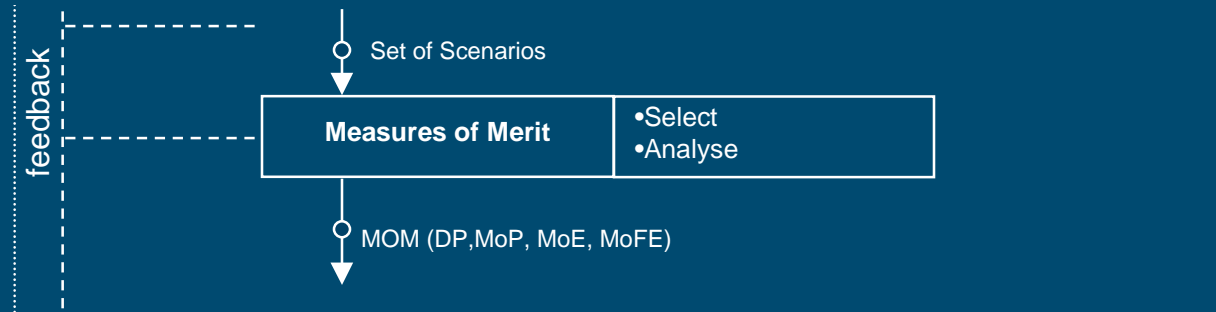
DP : Dimensional Parameters

MoP : Measures of C2 System Performance

MoE : Measures of C2 System Effectiveness

MoFE : Measures of Force Effectiveness

# Measures of Merit



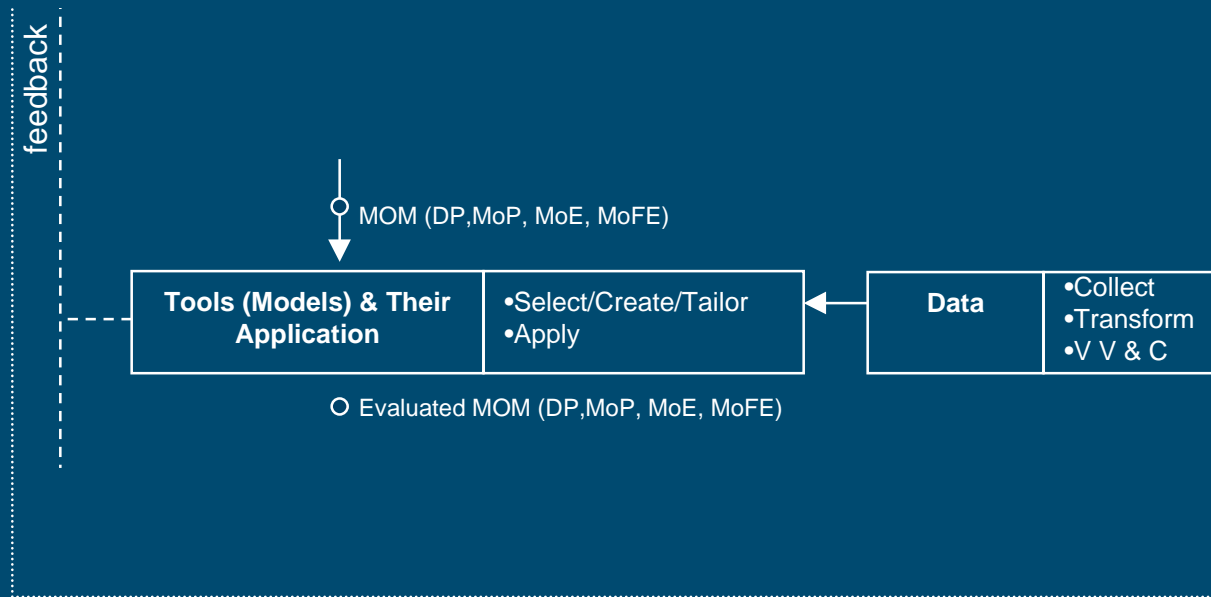
**DP** : radio and system architecture descriptions

**MoP** : Picture completeness, HQ planning efficiency, operational pace, organisation flexibility

**MoE** : ground controlled, enemy destroyed, casualties prevented

**MoFE** : battles won

# Tools, Models, Applications, and Data



- Simulation : C2IS & CLASS
- Benefits Analysis (MCDA)
- Vignette analysis by Military Advisory Panels
- Network Modelling

# Quantifying the MoEs

## Methods

C2IS /  
CLASS

Vignettes /  
MAP

Benefits  
Analysis

Flexibility

C2IS /  
CLASS

Queuing  
Model

Network  
Modelling

Pace

C2IS /  
CLASS

Vignettes /  
MAP

Manoeuvre

C2IS /  
CLASS

Reach

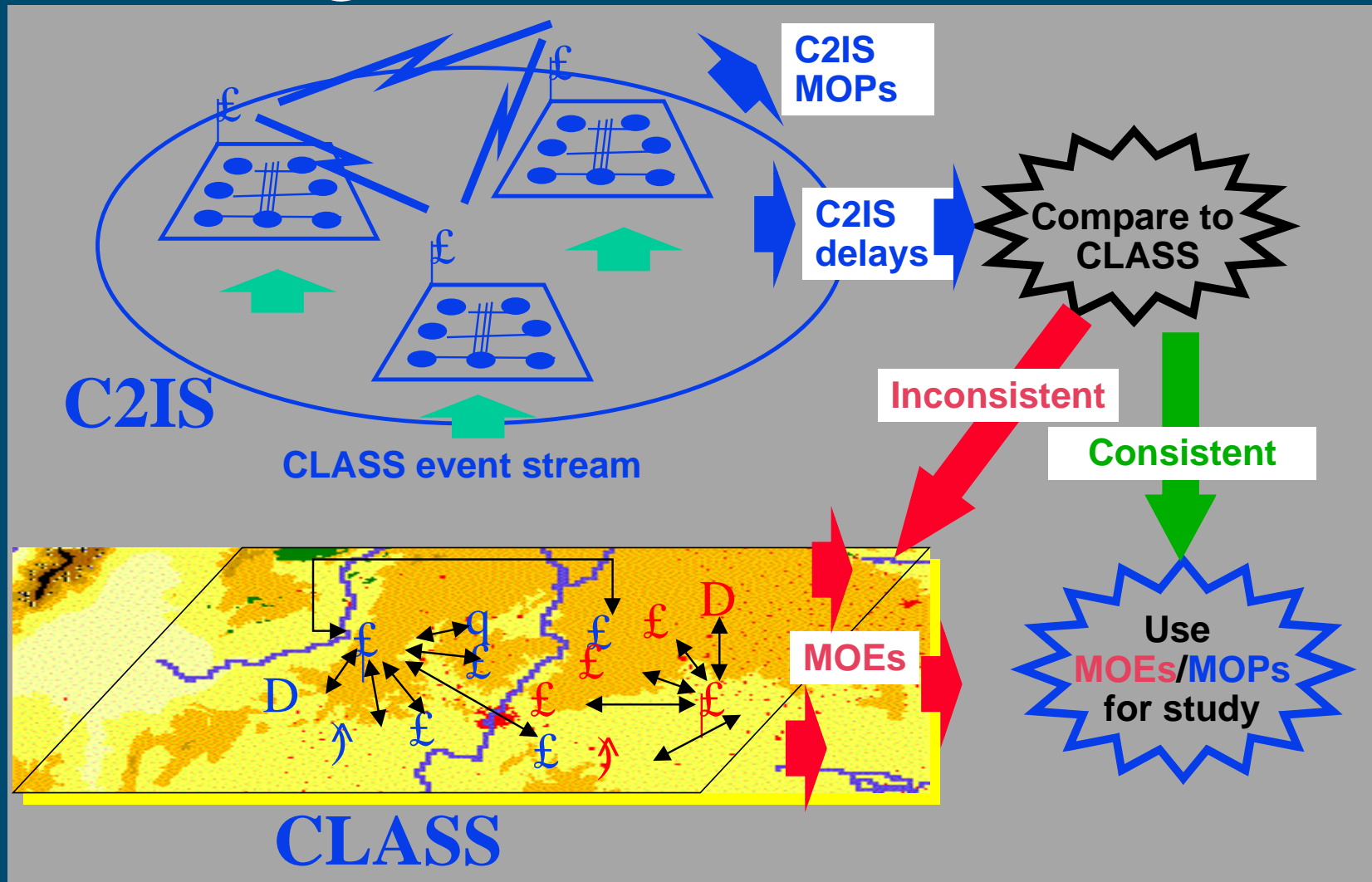
Communications  
deployment mode

Capacity

Contractors'  
modelling ?

Completeness

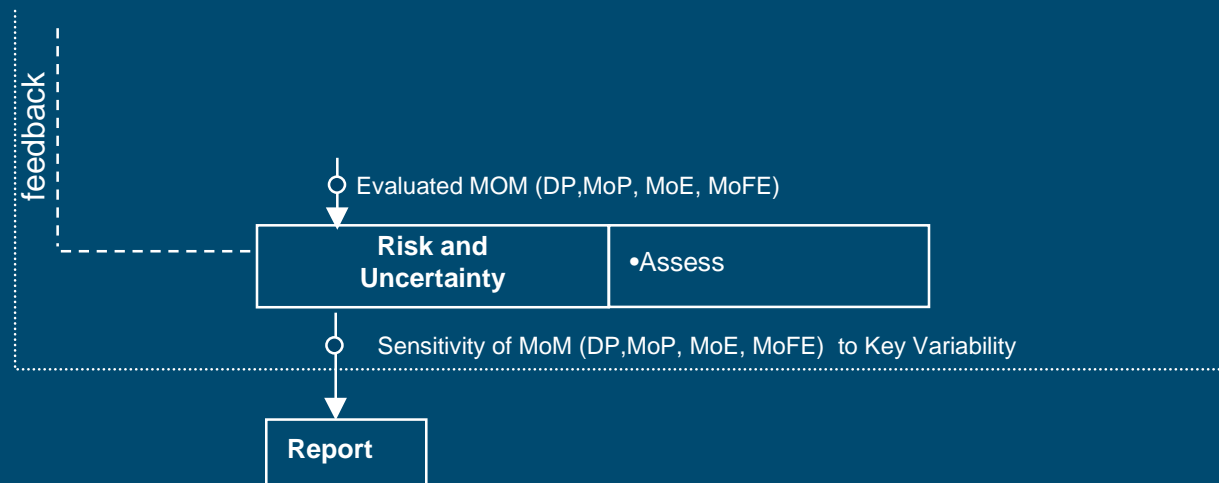
# Modelling - C2IS & CLASS



# Vignettes

- Deployment - Europe
- Enemy air strike on ARRC HQ
- Joint deep operation
- Transition to warfighting
- Coalition operations
- Exit from theatre

# Risk & Uncertainty



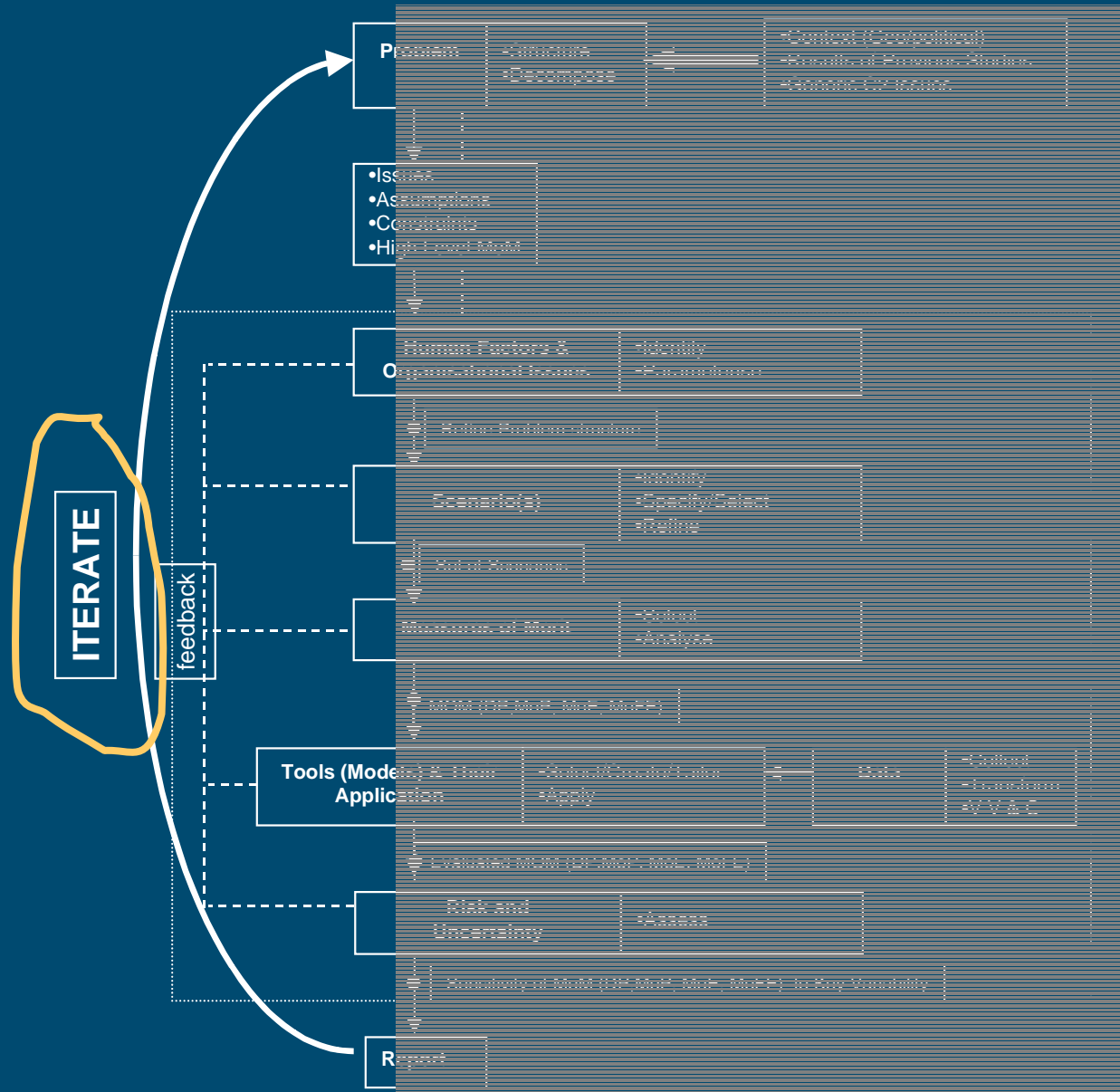
- Options for procurement not well defined until (too) late
- Cost data not available until late - commercial sensitivity
- Falcon within the system of systems - boundary issues unclear
- Information exchange requirements unclear

# Reporting

- Operational Analysis Supporting Paper
- Addresses evidence supporting
  - Need for the equipment
  - Justification for the scale of the investment to be made
  - Cost-effectiveness of the options for meeting the requirement
- Supporting briefings to MoD staffs
- N.B. A bound paper 'Report' is very unlikely

# Iteration

- Requirement Definition Study
- Pilot Study of methods
- Gained confidence of customers in HQ and Procurement
- Engaged with two generations of operators !



# Conclusion

- COBP powerful aid to good study design
- COBP strengths for Falcon
  - System of systems
  - Doctrine and organisation
  - Good communication - with the clients
- Way ahead
  - more applications
  - education of analysts